The Lunar Lander Neutron & Dosimetry (LND) Experiment on Chang'E4. R. F. Wimmer-Schweingruber[1], S. Zhang[2], J. Yu[1], C. E. Hellweg[3], J Guo[1], H. Lohf[1], T. Berger[3], S. I. Böttcher[1], S. Burmeister[1], A. Knappmann[1], V. Knierim[1], B. Schuster[1], L. Seimetz[1], Z. Xu[1], G. Shen[2], B. Yuan[2], [1]Institute of Experimental & Applied Physics, University of Kiel (CAU), Germany (wimmer@physik.uni-kiel.de), [2]National Space Science Center (NSSC), Chinese Academy of Science, Beijing, China, [3]Institute of Aerospace Medicine, DLR, Cologne, Germany

Introduction: Chang'E4, the Chinese mission to the Moon, launched on December 8, 2018 and landed on the far side of the Moon in the von Karman crater on January 3, 2019. The mission consists of a lander, a rover, and a communication relay. In this presentation we will describe first data from the Lunar Lander Neutron & Dosimetry experiment (LND) which is placed on the lander. LND consists of a stack of 10 segmented Si solid-state detectors (SSDs) which forms a particle telescope to measure charged particles (electrons fom 0.5 MeV to several MeV, protons 8-35 MeV, and heavier nuclei 17-75 MeV/nuc). A special geometrical arrangement allows observations of fast neutrons (and γ-rays) which are also important for dosimetry and cosmic-ray exposure of lunar soils. Thermal neutrons are measured using a very thin Gd conversion foil which is sandwiched between two SSDs. Thermal neutrons are sensitive to subsurface water and important to understand lunar surface mixing processes.

Despite the aim of landing humans on the Moon in the not too distant future, radiation measurements in the vicinity of the Moon are remarkably scarce. Fairly recent measurements in lunar orbit were provided by the Radiation Dose Monitor (RADOM) on board Chandrayaan-1 [1]. The spacecraft reached its operational 100 km circular orbit on November 12, 2008. Measurements showed a dose rate of 0.23 mGy per day averaged over 3545 hours of measurement time (20/11/2008 to 18/5/2009). Newer measurements have been provided by the Cosmic Ray Telescope for the Effects of Radiation (CRaTER) instrument [2] on board the Lunar Reconnaissance Orbiter (LRO). CRaTER measured a radiation exposure of about 0.22 − 0.27 mGy per day in its 50 km orbit. In comparison with these meager orbital data, there is a real dearth of data *on* the lunar surface. The current knowledge about the radiation environment on the surface of the Moon is based exclusively on calculations using radiation transport models with input parameters from models for the galactic cosmic ray spectra and for solar particle events. This is highly questionable, especially since we know that these models are fraught with uncertainties [3]. Measurements of the lunar neutron density at depths of 20 - 400 g/cm^2 within the lunar subsurface were performed during the Apollo 17 mission [4].

Science and Measurement Objectives: LND's chief purpose is to prepare for human exploration of the Moon by providing time series of dose rate and linear energy transfer (LET) spectra from the surface of the Moon. A secondary science objective is to investigate small-scale variations in the particle fluxes in conjunction with other near-Earth assets such as SOHO, ACE, etc. In addition, LND has two "lunar" science objectives, i.e., to measure the very local subsurface a) water and b) FeO content and to compare them with a larger average. To improve our knowledge of the surface radiation field on the Moon, LND measures at three time cadences 1) 1 minute: low energy resolution electrons, protons, neutrals, dosimetric qantities, 2) 10 minutes: thermal neutrons, electrons, heavy ions at low energy resolution 3) one hour: high-resolution data for ions, electrons, neutrons, dosimetric quantities (Fig. 2).

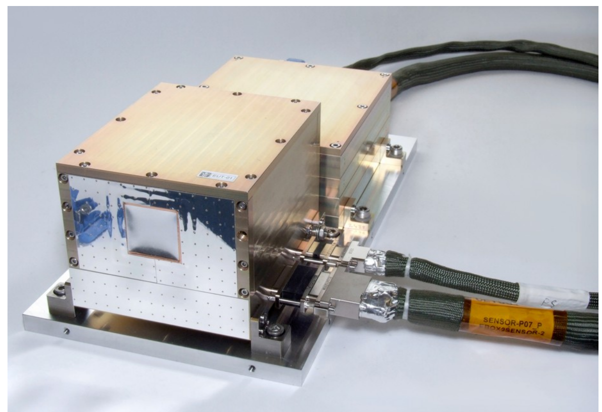

Fig. 1: The LND instrument before integration into the Chang'E-4 lander. The front "box" (sensor head) houses the detectors and front-end electronics, the rear one (electronics box) the back-end electronics, power supply, and interface to the lander.

Instrument Description: LND consists of a sensor head viewing the zenith direction and a separate electronics box. It is housed in the instrument compartment of the Chang'E4 lander. The sensor head houses a stack of 10 segmented SSDs, a single LND detector has a geometric factor of 28.3 cm^{2}sr, which allows for a high count rate of ∼35 counts/sec per single detector. The inner segments of the top two detectors have a geometric factor of 0.58 cm^2sr and we expect approximately 0.5 counts/sec in coincidence. This high count rate allows to determine statistically significant variations in the dose rate during solar particle events, and to determine particle spectra with high time resolution (see next section). LND can stop ~30 MeV protons and relativistic electrons.

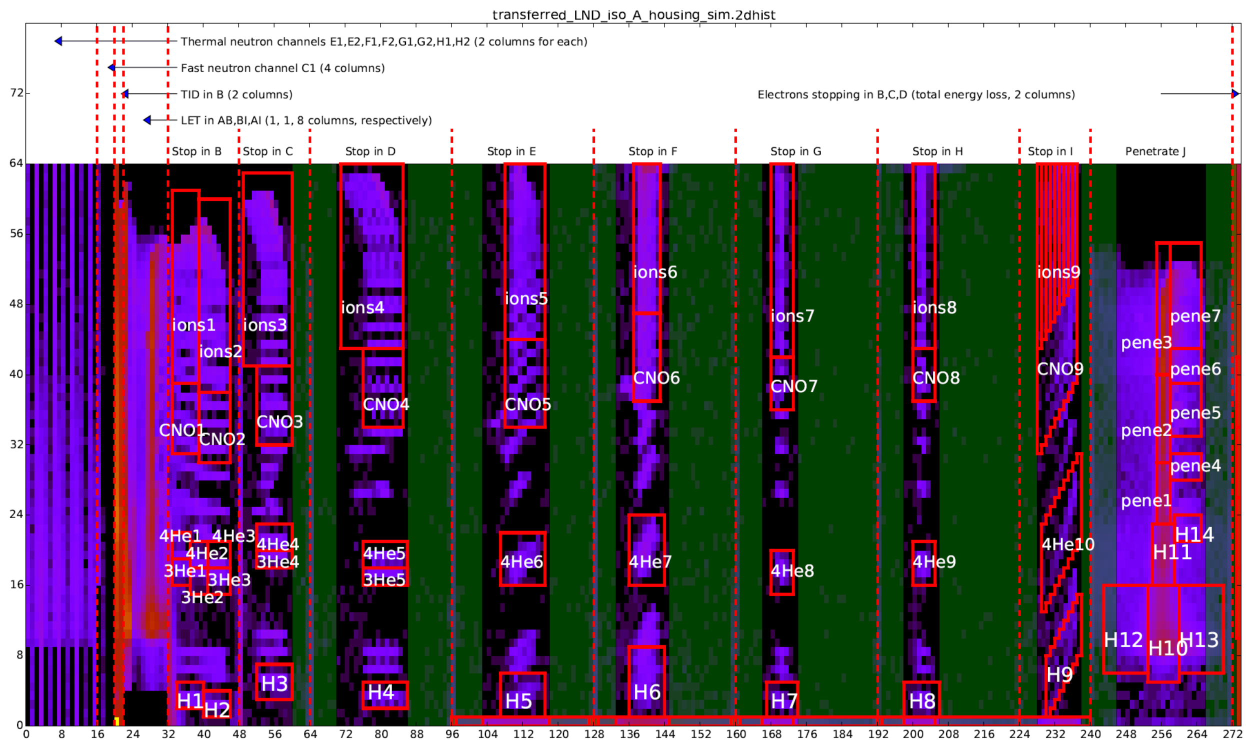

Fig. 2: LND data products are organized according to the detectors in which particles stop. Ion species are indicated in the appropriate boxes. Primary energy increases from left to right.

Description of Data Products: The LND data products, especially for ions, can be seen in Fig. 2. Mass of the ions increases towards the top of the Figure, energy towards the right. The color code is based on simulations which do not account for natural abundances. Such a "plot" is generated by LND every hour and represents the highest resolution routine data available. The counts in the red boxes in Fig. 2 are read out every 10 minutes or even every minute to allow for higher time resolution. For example, protons (marked by H in Fig. 2) are read out every minute, so a coarse, 14-bin proton energy spectrum can be acquired once a minute. The boxes marked by CNO in Fig. 2 are read out every 10 minutes, allowing acquisition of a coarse CNO energy spectrum once every 10 minutes if there are enough counts in the individual bins, e.g., during a large solar particle event.

Thermal and fast neutrons are mapped to the leftmost columns in Fig. 2. The thermal neutron energy spectra can be inverted for count rates of thermal neutrons which are indicative of subsurface water and FeO content. The fast neutron spectra can be inverted to determine the neutron energy spectrum which is important for radiation protection of future astronauts.

Similar to fast neutrons, electron spectra will need to be reconstructed from the rightmost red box and the ones in the very bottom row. Thus LND provides data products for all relevant particle species.

Current Status: Chang'E-4 was launched on December 8, 2018 and landed on the far side of the Moon on January 3, 2019. At the time of writing this abstract the LND team has not yet seen LND science data, as the lander and rover are still being commissioned.

We will present first data from LND at the 50th LPSC conference.

References:

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